A role of anesthesiologist in reducing surgical bleeding in endoscopic sinus surgery

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Key words: *anesthesia; functional endoscopic sinus surgery; intraoperative bleeding; induced hypotension.*

Summary. *Visibility in the surgical field reduced by bleeding is one of the most important problems of endoscopic sinus surgery. It causes the risk of serious complications and reduces intervention quality. Recently, an increasing number of patients undergo surgical interventions under general anesthesia. Since general anesthesia may influence surgical bleeding in physiological and pharmacological pathways, the role of an anesthesiologist is extremely important in reducing bleeding. The impact of different anesthesia methods on quality of the surgical field is being investigated, and the most effective medicines are being sought.*

Introduction

Chronic rhinosinusitis and chronic polypous rhinosinusitis are commonly detected diseases that affect a number of people. Currently, surgical treatment is used rather often. In functional endoscopic sinus surgery (FESS), classic local anesthesia in FESS is gradually being replaced by general anesthesia. General anesthesia has the following apparent advantages: an immobile surgical field for performing a surgical operation; effective protection of the respiratory tract; adequate analgesia and ventilation. The only serious limitation during general anesthesia is that bleeding is more intensive than during local anesthesia (1, 2). Surgical bleeding decreases visibility of the surgical field during an intervention and appears to be one of the most serious problems of FESS (2–4). Reduced visibility of the surgical field is related to an increased risk of dangerous vascular, orbital, and intracranial complications, prolonged duration of intervention, and reduced quality of intervention (1, 5, 6). Despite usually low bleeding volumes during FESS and rare cases of need for hemotransfusion, most authors indicate some risk of blood-borne infection (7, 8). The aim of this article is to review general factors that influence surgical bleeding during FESS and to discuss measures for reducing it.

Surgical bleeding

Surgical bleeding, which affects visibility of the surgical field during FESS interventions, is commonly local bleeding, which is difficult to control due to anatomical and pathological characteristics, and the specificity of surgical techniques. Bleeding is influenced by the position of the surgical table and patient's body temperature. It also may be physiologically and pharmacologically affected by general anesthesia.

Anatomical characteristics. Due to the wide vascular net in head tissues and specificity of a tissue structure, septa of blood vessels between connective tissue are strained, and head wounds cause heavy bleeding. Bleeding is more intensive in the areas next to large vessels. Stammberger (1), discussing surgical bleeding, indicates the following 4 typical areas related to more intensive bleeding during surgical manipulations: 1) *a. ethmoidalis anterior* location in the roof of the ethmoid labyrinth, especially in cases of damage to the osseous channel of the artery; 2) the branch of *a. sphenopalatina* in the area of the posterior end of the middle concha, especially when the middle concha is strongly pneumatized into the dorsal side; 3) in cases of the damaged branch of *a. sphenopalatina* when manipulations are made in the area of the sphenoid sinus hole; 4) during manipulations in the area of the posterior part of the inferior concha when the underside of the buccal sinus hole is widely broadened.

Surgical bleeding is classified into arterial, venous, and capillary. According to the opinion of Jacobi et al. (9), capillary bleeding is the most serious problem in endoscopic sinus surgery. Capillary circulation can be reduced by reducing arterial blood pressure and performing local vasoconstriction (1, 10).

Physiological regulation of circulation. The mean arterial blood pressure is an important factor related to the intensity of surgical bleeding (10, 11). It is directly proportional to cardiac output (CO) and

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general peripheral resistance. Under effect of autonomic nervous system, heart rate, heart impulse spread rate, and contraction power of the myocardium may be changed. In case of parasympathetic nervous system domination, the heart rate will be decreased, the impulse spread rate in the AV node will be slowed, and the contraction power of the myocardium will be decreased (12). CO also depends on blood volume flowing into the heart. The peripheral resistance is related to the activity of sympathetic nerve fibers. Parasympathetic stimulation causes vasodilatation (13). Blood pressure may be reduced during vasodilatation, i.e., in the case of decreasing resistance and/or cardiac output. The following physiological factors for reducing surgical bleeding are indicated: normal hemostatic response, arterial hypotension (decreased resistance and/or cardiac output), decreased venous blood pressure (the surgical field must be above the level of the heart, venous obstruction should be eliminated, intrathoracic pressure should be decreased) (14).

Specifics of surgical technique. As the surgical procedure is performed with an endoscope held in one hand and a surgical instrument in another, simultaneous blood elimination in the operation field is not possible. An endoscope must be cleaned frequently. The possibilities for local hemostasis are limited.

Position of surgical table. When the surgical field is above the level of the heart, blood inflow into the vessels will be reduced (postural ischemia), and blood outflow will be increased. Going up from the level of the heart, a decrease in systemic blood pressure (2 mm Hg) will be detected every 2.5 cm (15). The postural effect is well known and widely applied in head and neck surgery for the suppression of bleeding and improving the visibility of the surgical field. In combination with pharmacologic agents, this effect is used for controlled hypotension (15, 16). When the head of a surgical table is raised, especially with concomitant use of vasodilatators, blood will be deposited in the lower areas, and venous blood recurrence will be reduced, as well as the minute volume of the heart.

Body temperature. Sustaining normal body temperature during surgery is very important for reducing surgical bleeding. Even insignificant hypothermia would alter the function of platelets and coagulation, thus increasing blood loss (17, 18).

The role of general anesthesia in surgical bleeding. Hydrostatic arterial blood pressure can vary physiologically depending on changes in ventilation, as well as pharmacologically induced myocardium contractility and changes in the tonicity of peripheral blood vessels. Under normal conditions, pressure in the pleural cavity decreases during inspiration, and this facilitates blood inflow into the heart. Using intermittent positive pressure ventilation, positive intrathoracic pressure increases during inspiration, and this reduces venous blood return. Applied fixed positive pressure at the end of expiration limits venous return even more and at the same time reduces arterial blood pressure. During inspiratory phase, the inflow of blood into the heart significantly decreases, and passive expiration does not reduce this effect (10). In addition, bleeding increases in cases of higher chest pressure, e.g., during coughing or straining (19).

Choice of anesthetic agent

An anesthetic choice may also affect surgical bleeding. An inhalational anesthetic agent, halothane, is a medium-potency vasodilatator; it may reduce general peripheral resistance as much as 15% to 18%. Halothane causes the dilation of the blood vessels of the skin, brain, and internal organs and vasoconstriction in skeletal muscles. Enflurane has little effect on the resistance of blood vessels (10). Isoflurane is a strong, dose-dependent vasodilatator (20). This pharmaceutical agent is believed to act directly on the smooth muscles of the blood vessels and to decrease systemic blood vessel resistance. Subsequently, it reduces arterial blood pressure. Despite the lower perfusion pressure, tissue perfusion is increased following vasodilatation. Isoflurane may increase the velocity of blood flow in the muscles two or even three times (2). Therefore, isoflurane usage during FESS may increase perfusion of the nasal mucous membrane and surgical bleeding as well.

An application of an intravenous anesthetic agent, propofol, during FESS reduces surgical bleeding and provides better conditions for surgical operation in comparison with common inhalational anesthetics. When general anesthesia is required, a combination of nitrogen suboxide and opiate analgetics is used (20). Similarly to isoflurane, propofol may decrease systolic blood pressure by 20% to 48%, by reducing heart contractility and systemic blood vessel resistance. When anesthesia is caused by propofol infusion, stimulation of endotracheal intubation and pain during the surgical operation may normalize arterial blood pressure, while cardiac output may remain unaffected (21). During such anesthesia with propofol, systemic vasodilatation is less significant compared to anesthesia with isoflurane. During endoscopic sinus surgical operations, the longest period is spent on the ethmoid sinus-related manipulations. The ethmoid, sphenoid, and frontal sinuses are supplied with blood by the branches of *a. carotis interna*: the ethmoidal artery and the supraorbital artery. Propofol is known to reduce cerebral circulation and metabolism (2). Therefore, by reducing cerebral circulation and arterial blood inflow with propofol, circulation in the ethmoid, sphenoid, and frontal sinuses will be suppressed and working conditions in the surgical field will be improved. There are no differences in blood pressure in peripheral tissues, including the maxillary sinus, as both propofol and isoflurane are known as vasodilatators. The peripheral circulation-related effect of propofol depends on the suppressing of the central (cerebral) sympathetic blood vessel tonicity, whereas isoflurane has a directly relaxing effect on the smooth muscles of blood vessels (21).

Sevoflurane, a modern inhalational anesthetic, is not the most adequate medicine for anesthesia in the case of FESS interventions. A study by Sivaci et al. showed that intraoperative blood loss amounted to 296.9±97.6 mL during anesthesia with sevoflurane and fentanyl and such blood loss was only 128.1±37.3 mL ($P<0.01$) during anesthesia with propofol and fentanyl (22). Less bleeding in the propofol group is related to better visibility of surgical field. Other authors also indicate that propofol has advantages over sevoflurane during endoscopic paranasal sinus surgical interventions (21).

Barbiturates and etomidate have a less significant effect on the cardiovascular system compared to propofol (10). Myocardial contractility is reduced and peripheral vasodilatation is observed, especially if high doses are used or the medicine is injected faster. Arterial blood pressure is decreased especially in patients with hypovolemia or cardiac disease. Ketamine causes a 25% increase in arterial blood pressure and 20% increase in heart rate. Therefore, cardiac output increases. Following sympathetic stimulation, vasodilatation is observed in tissues with alpha-adrenergic receptors and vasoconstriction is observed in tissues with dominating beta-adrenergic receptors.

Opioids may cause a drop in blood pressure during anesthesia, minimize hemodynamic response to surgical stress, and subsequently reduce surgical bleeding (23). Sufentanil and remifentanil have some advantages over fentanyl in maintaining hemodynamic stability, as well as better working conditions in the surgical field (24). Nitrogen suboxide is an adequate component of anesthesia during FESS (25).

High doses of benzodiazepines, especially in interaction with opioids, reduce cardiac output and systemic blood pressure. Hypotension is more frequent in patients with hypovolemia. Benzodiazepines facilitate the effect of ganglion blockers and other hypotensive pharmacological agents (25).

Depolarizing myorelaxants cause adverse hemodynamic effects due to the blockade of autonomic ganglions, inhibition of parasympathetic and heart muscarinic receptors, and leads to the degranulation of mast cells and release of free histamine (10). Due to autonomic ganglion blockade, the sympathetic stimulation is suppressed and blood cell systemic resistance is decreased. The released histamine reduces peripheral resistance and myocardial contractility. It is thought that vasodilation induced by released histamine is the main cause of hypotension development.

Impact of anesthetic agents on platelet function. Dogan et al. have investigated the impact of isoflurane, sevoflurane, and propofol on platelet aggregation. The studies in vitro have demonstrated a significant inhibiting effect on platelets caused by sevoflurane and propofol and no inhibiting effect caused by isoflurane (26). Therefore, the latter agent is suitable for surgical operations related to a severe risk of bleeding. However, Law et al. have demonstrated no significant differences in bleeding between isoflurane and propofol groups (20 vs. 18 patients with I–III ASA class) after using these agents for anesthesia when an equal reduction of arterial blood pressure was applied. Moreover, during thromboelastography tests, there were no differences between the groups. The authors reported no increase in propofol-related risk of bleeding (27). Peripheral vasodilatators – nitroprusside and nitroglycerin – affect platelets by inhibiting their aggregation. It thought that nitroglycerin has a smaller and clinically insignificant effect on platelets comparing to nitroprusside (28).

Controlled hypotension

Controlled hypotension can be used as a specific measure in reducing surgical bleeding, especially in possible cases of more extensive blood loss: in the presence of extended pathological process, scheduling a large-scale intervention, and performing repeated surgical interventions. Controlled hypotension is defined as a pharmacologically induced reduction in arterial blood pressure to 50–70 mm Hg of mean value under general anesthesia, applying artificial pulmonary ventilation (16). The hypotension state is achieved by reducing peripheral blood vessel resistance, reducing cardiac output, or using a combination of both. Cardiac output is affected by changing the blood inflow into the heart and the heart rate (10, 16). Peripheral vasodilatation is related to sympathetic activity; vasodilatation is caused by terminating sympathetic stimulation. Hypotension is induced by reducing total peripheral resistance; this may be achieved using vasomotor center-affecting medicines (the central effect) or by affecting sympathetic ganglia, postganglionic noradrenergic (alpha) terminals, as well as by directly affecting the walls of blood vessels (the peripheral level).

Hypotensive pharmaceuticals. There is no unified classification for hypotensive medicines. The ideal pharmaceutical agents for inducing controlled hypotension should meet the following requirements: easy and safe to use, predictable and controlled action, fast onset of action and decline, fast elimination without any tendency to accumulate (23). However, in practice this is not fully achieved due to the absence of ideal pharmacological agents meeting these requirements.

Inhalational anesthetics, nitroprusside, nitroglycerine, trimethaphan, alprostadil, and adenosine are the main drugs used for controlled hypotension. β-Adrenoreceptor antagonists (labetalol, esmolol), calcium channel blockers (verapamil, diltiazem, nicardipine), fenoldopam may be used for the induction of controlled hypotension as monomedicines or in combination with other medicines as a supplementary substance for sustaining the effect of the main substance. Third substances (ACE inhibitors [captopril], α2-adrenoreceptor agonists [clonidine, dexmedetomidine], opioids, and intravenous anesthetics) may be used as supplementary substances to potentiate the hypotensive effect of the main substances and/or to prevent reflex tachycardia or rebound hypertension. At this time, controlled hypotension is caused by a combination of a few medicines (16, 25). This allows a rather simple and precise hypotension control as well as reduction of the possibility of an overdose.

The usage of β-adrenoreceptor blockers (esmolol) for controlled hypotension during endoscopic paranasal sinus surgery causes less intensive bleeding and better working conditions in the surgical field compared to nitroprusside (3). During the development of hypotension, endogenic catecholamines are released, and sympathetic tonus is increased due to α-adrenergic effect of catecholamines. Esmolol blocks the adrenergic effect of vasoactive amines on the heart. In this respect, nitroprusside causes general vasodilatation, reflex tachycardia and increases cardiac output. Vasodilatation and higher cardiac output cause more intensive blood circulation in the capillaries of the nose and sinus mucous membrane (3). For controlled hypotension during endoscopic sinus surgery, good results are achieved with nitroglycerine (4) or a combination of nitroglycerine and captopril (29). Low doses of nitroglycerine cause stronger venous dilatation and have a weaker effect on arterioles. Choosing an optimal position of the surgery table creates prerequisites for "postural" hypotension and also results in better visibility of surgical field. Isoflurane is successfully used for controlled hypotension during FESS. Although isoflurane at a higher dose causes hypotension, it does not affect cerebrovascular blood supply, but brain metabolic activity and oxygen need are reduced. Inhalation anesthetics have certain advantages: simple dosage, no special usage conditions, concomitant anesthetic and hypotensive effect (21). Currently, extensive research on the effect of other medicines (adenosine, prostaglandin E1, and dexmedetomidine) on the quality of surgical field visibility during sinus surgery is being carried out (25).

Limitations of controlled hypotension. These limitations are related to reduced perfusion reserves in the main organs. Cardiovascular diseases play the most important role in such changes in reserves. Kleinschmidt indicates cerebrovascular insufficiency, ischemic heart disease, heart defects, significant heart failure, and increased intracranial pressure as contraindications for controlled hypotension (23). Relative contraindications are arterial hypertension; pulmonary, hepatic, and/or renal dysfunction; severe anemia; and hypovolemia (16).

Monitoring. Due to the potential risks during controlled hypotension, continuous and reliable monitoring of vital signs is required. According to the standards, ECG (ST segment analysis), arterial blood pressure (using the direct method), central venous pressure, diuresis, body temperature should be monitored, pulse oximetry, capnometry, arterial blood gas and acid-alkali balance, hemoglobin, hematocrit and electrolyte tests should be performed (16).

Concluding remarks

The issue of surgical bleeding is relevant and complicated in endoscopic paranasal sinus surgery. Bleeding is difficult to control in this surgical area for anatomical and surgical technique reasons. Anesthesia methods and the choice of the anesthetic agent may influence surgical bleeding, the quality of surgical field visibility during functional endoscopic sinus surgery; therefore, the role of the anesthesiologist in improving conditions of surgical intervention is extremely important. The correct surgical table position is important for securing sufficient venous outflow from the surgical field. Anesthesia must be adequate, i.e., any sympathetic stimulation effect should be eliminated. Hypothermia must be avoided during surgery, while normocapnia is welcome. When general anesthesia is applied, intravenous administration of the general anesthetic propofol may be related to reduced surgical bleeding and better field visibility during the operation. Controlled hypotension should be used in cases of a scheduled large-scale intervention and possible severe surgical bleeding. Controlled hypotension can be induced by both specific medicines and anesthetic agents.

Anesteziologo vaidmuo mažinant operacinį kraujavimą endoskopinėje prienosinių ančių chirurgijoje

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Raktažodžiai: anestezija, endoskopinė sinusų chirurgija, operacinis kraujavimas, valdoma hipotenzija.

Santrauka. Operacinio lauko matomumą mažinantis kraujavimas – viena pagrindinių endoskopinės prienosinių ančių chirurgijos problemų. Kyla pavojingų komplikacijų grėsmė, nukenčia intervencijos kokybė. Dabar vis daugiau pacientų operuojami taikant bendrąją anesteziją. Tačiau bendroji anestezija gali turėti įtakos operaciniam kraujavimui fiziologiškai ir farmakologiškai, todėl anesteziologo vaidmuo, mažinant operacinį kraujavimą, tampa ypač svarbus. Tyrinėjama įvairių anestezijos metodikų įtaka operacinio lauko kokybei, ieškoma tinkamiausių medikamentų.

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Received 6 January 2009, accepted 5 November 2010
Straipsnis gautas 2009 01 06, priimtas 2010 11 05